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⑤4 Slurry hydroprocessing staged process.

(57) A novel slurry hydrotreating process is described in which a hydrotreating catalyst of small particle size is contacted with petroleum or synfuel feedstocks, particularly gas oils, for hydrogenation of the aromatics contained in such feedstocks. The slurry hydrotreating process employs a high temperature stage followed by one or more low temperature stages.

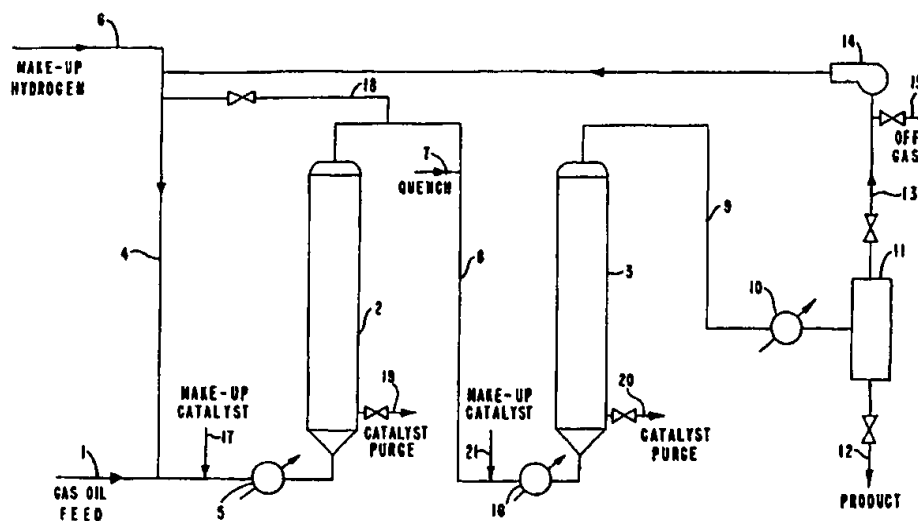


FIG. 1

## SLURRY HYDROPROCESSING STAGED PROCESS

BACKGROUND OF THE INVENTION

This invention relates to a process employing a catalyst slurry for the hydrotreating of a heavy fuel oil.  
 5 More particularly, the process comprises a high temperature hydrotreating stage followed by one or more lower temperature stages.

The petroleum industry employs hydrotreating to upgrade the quality of gas oils in order to make them suitable as a feedstock to a fluid catalytic cracker (FCC). Hydrotreating accomplishes the hydrogenation of multi-ring aromatic compounds contained in gas oils to one-ring aromatics or completely saturated  
 10 naphthenes. This is necessary to assure low coke and high gasoline yields in the cat cracker. Multi-ring aromatics cannot be cracked effectively to mogas (motor gasoline) and heating oil products, whereas partially hydrogenated aromatics or naphthenes can be cracked to premium products in the naphtha and heating oil boiling range. Hydrotreating is further capable of removing sulfur and nitrogen which is detrimental to the cracking process.

15 Conventional processes for hydrotreating heavy feeds, whether utilizing a fixed bed or a slurry system, have inherent limitations. The catalyst employed in the hydrotreater becomes poisoned by organic nitrogen containing compounds in the feed being treated, wherein such compounds are adsorbed onto the catalyst and tie up its hydrogenation sites due to the slow kinetics or turnover for hydrodenitrogenation. Desirable hydrotreating reactions are thereby hindered. For example, the catalyst becomes incapable of saturating  
 20 aromatic compounds in the feed fast enough. Higher temperatures are frequently needed to counter the poisoning effect of such compounds. However, at higher temperatures, thermodynamic equilibrium tends to favor the preservation of undesirable multi-aromatic compounds.

According to the present invention, a slurry hydrotreating process employing temperature staging provides a means to circumvent both the kinetic and equilibrium limits conventionally encountered in either  
 25 fixed bed or slurry hydrotreating processes.

Hydrotreating processes utilizing a slurry of dispersed catalysts in admixture with a hydrocarbon oil are generally known. For example, Patent No. 4,557,821 to Lopez et al discloses hydrotreating a heavy oil employing a circulating slurry catalyst. Other patents disclosing slurry hydrotreating include U.S. Patents  
 30 Nos. 3,297,563; 2,912,375; and 2,700,015.

Staging of reactors in a hydrotreating process is also generally known. For example, U.S. Patents Nos. 3,841,996 and 3,297,563 disclose slurry hydrotreating reactions that can be operated with a plurality of stages. However, the advantages of operating the subsequent stages at lower temperatures were not recognized. U.S. Serial No. 009808, filed February 2, 1987 (published EP application 277,718A) discloses  
 35 staged fixed bed reactors at successively lower temperatures in order to promote equilibrium limited aromatic saturation reactions in a hydrocarbon oil. The advantages of temperature staging revealed in this reference for fixed bed operations, however, are minimal compared to the results obtained in the present invention wherein temperature staging is utilized in a slurry process.

BRIEF DESCRIPTION OF THE INVENTION

40 The present invention teaches a method of maximizing hydrogenation rates while avoiding equilibrium limits in a slurry hydrotreating process, wherein a hydrotreating catalyst of small particle size is contacted with petroleum or syngas feedstocks for hydrogenation of aromatics and removal of organic nitrogen. The  
 45 slurry hydrotreating process employs a high temperature stage followed by one or more low temperature stages.

These and other objects are accomplished according to applicants, invention, which comprises:

- 50 (1) contacting a gas oil feedstock with hydrogen in a relatively high temperature first hydrotreating zone in the presence of a hydrotreating catalyst slurry such that substantial hydrodenitrogenation and saturation of the feedstock is carried out;
- (2) contacting the effluent from the first hydrotreating zone in the presence of a hydrotreating catalyst slurry with further hydrogen in a relatively low temperature second hydrotreating zone; and
- (3) separating hydrogen gas and catalyst from the product of the second hydrotreating zone to yield a hydrotreated product.

BRIEF DESCRIPTION OF THE DRAWINGS

The process of the invention will be more clearly understood upon reference to the detailed discussion  
 5 below upon reference to the drawings wherein:

FIG. 1 shows a schematic diagram of one process scheme according to this invention comprising a two stage hydrotreating slurry reaction.

FIG. 2 shows a graph illustrating that temperature staging can double the effectiveness of slurry hydrotreating for improving the quality of the hydrotreated product for use as catalytic cracker feed.

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DETAILED DESCRIPTION OF THE INVENTION

15 It has now been found that hydrogenation rates of a gas oil can be maximized and equilibrium limits avoided by operating a slurry hydrotreating process with two or more stages, preferably well mixed isothermal stages. According to the present invention, a relatively high temperature stage is followed by one or more low temperature stages. For example, a two stage process might process fresh feed in a 760° F stage and process the product from the first stage in a 720° F stage. Alternatively, several stages can be  
 20 operated at successively lower temperatures, such as a 780° F stage followed by a 740° F stage followed by a 700° F stage. Such an arrangement provides, in the first stage, fast reaction rates and, in the final stage or stages, lower equilibrium multi-ring aromatics levels (hence greater kinetic driving forces).

The slurry hydrotreating process of the present invention can be used to treat various feeds from fossil fuels such as heavy catalytic cracking cycle oils (HCCO), coker gas oils, and vacuum gas oils (VGO), which  
 25 contain high concentrations of aromatics. Similar feeds derived from petroleum, coal, bitumen, tar sands, or shale oil are also suitable.

Suitable feeds for processing according to the present invention include those gas oil fractions which are distilled in the range of 500 to 1200° F, preferably in the 650 to 1100° F range. Above 1200° F it is difficult or impossible to strip all of the feed off the catalyst with hydrogen and the catalyst tends to coke  
 30 up. Also, the presence of concarbon and asphaltenes gum up the catalyst. The feed should not be such that more than 10% boils above 1050° F. The nitrogen content is normally greater than 1500 ppm. The 2+ ring aromatics represent 50% or more and the 3+ ring aromatics content of the feed should generally should represent 25% or more by weight.

Suitable catalysts for use in the present process are well known in the art and include, but are not  
 35 limited to, molybdenum (Mo) sulfides, mixtures of transition metal sulfides such as Ni, Mo, Co, Fe, W, Mn, and the like. Typical catalysts include NiMo, CoMo, or CoNiMo combinations. In general sulfides of Group VII metals are suitable. (The Periodic Table of Elements referred to herein is given in Handbook of Chemistry and Physics, published by the Chemical Rubber Publishing Company, Cleveland, Ohio, 45th  
 40 Edition, 1964.) These catalyst materials can be unsupported or supported on inorganic oxides such as alumina, silica, titania, silica alumina, silica magnesia and mixtures thereof. Zeolites such as USY or acid micro supports such as aluminated CAB-O-SIL can be suitably composited with these supports. Catalysts formed in-situ from soluble precursors such as Ni and Mo naphthenate or salts of phosphomolybdic acids are suitable.

In general the catalyst material may range in diameter from 1  $\mu$  to 1/8 inch. Preferably, the catalyst  
 45 particles are 1 to 400  $\mu$  in diameter so that intra particle diffusion limitations are minimized or eliminated during hydrotreating.

In supported catalysts, transition metals such as Mo are suitably present at a weight percent of 5 to 30%, preferably 10 to 20%. Promoter metals such as Ni and/or Co are typically present in the amount of 1 to 15%. The surface area is suitably about 80 to 400 m<sup>2</sup>/g, preferably 150 to 300 m<sup>2</sup>/g.

50 Methods of preparing the catalyst are well known. Typically, the alumina support is formed by precipitating alumina in hydrous form from a mixture of acidic reagents in an alkaline aqueous aluminate solution. A slurry is formed upon precipitation of the hydrous alumina. This slurry is concentrated and generally spray dried to provide a catalyst support or carrier. The carrier is then impregnated with catalytic metals and subsequently calcined. For example, suitable reagents and conditions for preparing the support  
 55 are disclosed in U.S. patents Nos. 3,770,617 and 3,531,398, herein incorporated by reference. To prepare catalysts up to 200 microns in average diameter, spray drying is generally the preferred method of obtaining the final form of the catalyst particle. To prepare larger size catalysts, for example about 1/32 to 1/8 inch in average diameter, extruding is commonly used to form the catalyst. To produce catalyst

particles in the range of 200  $\mu$  to 1/32 inch, the oil drop method is preferred. The well known oil drop method comprises forming an alumina hydrosol by any of the teachings taught in the prior art, for example by reacting aluminum with hydrochloric acid, combining the hydrosol with a suitable gelling agent and dropping the resultant mixture into an oil bath until hydrogel spheres are formed. The spheres are then  
 5 continuously withdrawn from the oil bath, washed, dried, and calcined. This treatment converts the alumina hydrogel to corresponding crystalline gamma alumina particles. They are then impregnated with catalytic metals as with spray dried particles. See for example, U.S. Patents Nos. 3,745,112 and 2,620,314.

In the slurry hydrotreating process of the invention, fresh or reactivated catalyst can be continually added while aged or deactivated catalyst can be purged or regenerated. The reactivated catalyst is  
 10 preferably continuously recycled to the reactor. Consequently, a slurry hydrotreating process can be operated at more severe conditions than a fixed bed hydrotreater, which typically operates for 1 or 2 years before it becomes necessary to shut it down in order to replace the catalyst.

Referring to FIG. 1, a feed stream 1, by way of example consisting of a gas oil feed, is introduced into a first slurry hydrotreating reactor 2 operated at a relatively higher temperature compared to a second slurry  
 15 hydrotreating reactor 3. Before being passed to the hydrotreater reactor 2, the feedstream 1 is typically mixed with a hydrogen containing gas stream 4 and heated to reaction temperature in a furnace or pre-heater 5. A make-up hydrogen stream 6 may be introduced into the recycle hydrogen supply stream 4 to the hydrotreating reactor 2. The hydrotreating reactor 2 contains typically 10 to 70 percent catalyst, preferably about 40 to 60 percent solids by weight. The feed may enter through the bottom of the reactor  
 20 and bubble up through an ebulating or fluidized bed. Recycle of the reactor effluent via a pump (not shown) is optional to recycle a portion of the feed for reactor mixing. The effluent stream 8 from the first hydrotreating reactor 2 is suitably lowered in temperature by either introducing a quench feed stream 7 and/or passing the effluent through a cooler 16. In addition, further hydrogen gas is suitably introduced via stream 18 into the first hydrotreating reactor effluent stream 8 before the latter is passed into the second  
 25 hydrotreating reactor 3. The effluent from this second reactor is suitably passed via stream 9 through a cooler 10, and into a gas-liquid separator or disengaging means 11 to take off gases, principally hydrogen, before yielding a liquid product stream 12. In many cases, the liquid products are given a light caustic wash to assure complete removal of  $H_2S$ . Small quantities of  $H_2S$ , if left in the product, will oxidize to free sulfur upon exposure to the air, and will cause the product to exceed pollution or corrosion specifications.

Depending on the size of the catalyst particles used therein, the hydrotreating reactors 2 and 3 may  
 30 optionally have filters at entrance and/or exit orifices to keep the catalyst particles inside the reactors. The reactors may alternatively have a flare (increasing diameter) configuration such that when the reactor is kept at minimum fluidization velocity, the catalyst particles are prevented from escaping through an upper exit orifice.

As indicated above, the hydrotreating reactors are arranged in descending temperature such that the  
 35 last reactor is between 650 and to 750 °F where equilibrium is favorable for hydrogenation of aromatics to one ring aromatics. The first stage is at a more elevated temperature, for example between 700 to 800 °F where more rapid hydrodenitrogenation (HDN) can occur.

Referring again to FIG. 1, the gas-liquid separator or disengaging means 11 separates the liquid  
 40 product from hydrogen gas along with ammonia and hydrogen sulfide by-products of the hydrotreating reactions and recycles them in gas stream 13 via compressor 14 back for reuse in the recycle hydrogen supply stream 4. An off gas stream 15 may be removed from the gas stream 13. The gas stream 13 is usually passed through a scrubber (not shown) to remove hydrogen sulfide and ammonia because of their inhibiting effects on the kinetics of hydrotreating and also to reduce corrosion in the recycle circuit.

The catalyst used in the hydrotreating reactors 2 and 3 is preferably reactivated on a continuous basis  
 45 as described in copending application S.N. 414,166, herein incorporated by reference. Spent catalyst may be removed from the reactors 2 and 3 via streams 19 and 20, respectively. Fresh make-up catalyst may be introduced via streams 17 and/or 21 into the feed stream 1.

The operating conditions in the hydrotreating reactors depend to some extent on the particular feed  
 50 being treated. The first hydrotreating reactor is suitably at a temperature of between 700 and 800 °F, preferably between 750 and 780 °F and at a pressure of 800 to 4000 psig, preferably 1500 to 2500 psig. The hydrogen treat gas rate is 1500 to 10,000 SCF/B, preferably 2500 to 5000 SCF/B. The space velocity (WHSV) or holding time is suitably 0.2 to 5, preferably 0.5 to 2.

The second (low temperature) hydrotreating reactor operates at a temperature between about 650 and  
 55 750 °F, preferably between 675 and 725 °F and a pressure of 800 to 4000 psig, preferably 1500 to 2500 psig. The hydrogen treat gas ratio is 1500 to 10,000 SCF/B, preferably 2000 to 5000 SCF/B. The space velocity (WHSV) is 0.2 to 5, preferably 0.5 to 2.

COMPARATIVE EXAMPLE 1

For comparison to the present staged hydrotreating process, single stage runs were conducted as follows. Commercial hydrotreating catalyst, KF-840, was crushed and screened to 32/42 mesh size. Catalyst properties are shown in Table I. This crushed catalyst was then sulfided overnight using a 10% H<sub>2</sub>S in H<sub>2</sub> gas blend. A 30.9 gram sample of the presulfided catalyst was added to a 300 cc stirred autoclave reactor along with 100 cc's of a heavy feed blend comprised of heavy vacuum gas oils, heavy coker gas oils, coker bottoms and heavy cat cracked cycle oil. Properties of the feed are listed in Table II.

Table I

Catalyst Properties	
NiO, Wt%	3.8
MoO <sub>3</sub> , Wt%	19.1
P <sub>2</sub> O <sub>5</sub> , Wt%	6.4
Surface Area, m <sup>2</sup> /gm	175.0
Pore/volume, cm <sup>3</sup> /gm	0.38

Table II

Feedstock Properties	
Sulfur, Wt%	1.63
Nitrogen, Wt%	0.39
Carbon, Wt%	87.63
Hydrogen, Wt%	9.60
Gravity, ° API	9.2
<u>Wt% Aromatics</u> <u>by HPLC</u>	
Saturates	26
1 Ring	9
2 Ring	10
3+ Ring	43
Polar Aromatics	12
<u>GC Distillation,</u> <u>F</u>	
5%	665
20%	753
50%	882
80%	1004
95%	1150

The autoclave was heated to 690 ° F under 1200 psig hydrogen pressure. The autoclave was operated in a gas flow thru mode so that hydrogen treat gas was added continuously while gaseous products were taken off. This hydrogen was added over the course of the run and the initial hydrogen charge plus make-up hydrogen was equivalent to 3500 SCF/B of liquid charged to the autoclave. After two hours at reaction conditions, the autoclave was quenched or cooled quickly to stop reactions. The autoclave reactor was depressured and the catalyst was filtered from the liquid products. These products were then analyzed to determine the extent of HDS, HDN, and aromatics hydrogenation. The results are shown in Table III. Similar experiments were conducted with the same catalyst and feed, but at reaction temperatures of 720, 730, 750, and 780 ° F. The results of these experiments are shown in Table III.

Table III

1200 Psig, 31.5 wt% Catalyst on Feed, 2 Hours at Temperature, 3500 SCF/B Hydrogen					
Slurry Hydrotreating Temperature, °F	690	720	730	750	780
Slurry Product Quality					
Wt% Sulfur	.215	.065	.047	.019	.001
Wt% Nitrogen	.122	.088	.086	.051	.028
Wt% Sats + 1R AR	64	63	63	64	61
Wt% 3+ R AR & Polars	21	18	22	22	25
Wt% Polar AR	2.2	1.2	1.6	1.1	0.7
MAT Conversion	58.9	63.3	61.2	60.5	57.2
MAT Coke	2.87	3.12	3.00	2.95	2.67

The results of Table III show that product sulfur, nitrogen and polar aromatics were all reduced by hydrotreating at higher temperatures and that heavy, 3+ ring aromatics were reduced by increasing the temperature from 690 to 720 °F. However, further increases in temperature resulted in higher heavy aromatics levels. This minimum 3+ ring aromatics concentration at relatively low temperatures indicates that aromatics saturation equilibrium limits heavy aromatics saturation at temperatures above 720 °F. Saturates plus 1 ring aromatics levels tend to remain constant over a broad temperature range from 690 to 750 °F before falling as hydrotreating temperature was increased from 750 to 780 °F. This indicates that equilibrium limits the production of compounds which can be converted to mogas in an FCC unit at hydrotreating temperatures of 750 °F or more.

The net effect of the impact of hydrotreating temperature on FCC feed quality was evaluated by the well known (MAT) Micro-activity Test which is described, for example, in the oil Gas Journal, 1966, Vol. 64, No. 39 at pages 7, 84, and 85; and the November 22, 1981 edition of the Oil and Gas Journal at pages 60-68. An equilibrium cracking catalyst from a commercial FCC unit was used in the MAT to crack each of these hydrotreated products. High MAT conversions to mogas and lighter products are desirable. Low MAT coke yields are desirable. The highest conversion was achieved by hydrotreating at 720 °F, but the lowest MAT coke yields were achieved at the highest temperature tested, 780 °F. Products with both high MAT conversion and low MAT coke yields could not be produced at a single hydrotreating temperature.

## EXAMPLE 2

To illustrate the staged process according to the present invention, an experiment similar to Comparative Example 1 above was conducted with the same catalyst and feed. However, in this experiment the autoclave was heated to 760 °F and held for one hour. Then the autoclave was quickly (in 10 sec or less) cooled to 720 °F and held for an additional hour before quenching to halt all reactions. This temperature staging experiment was repeated by heating to 750 °F and holding for one hour, followed by one hour at 690 °F. The results of these experiments are shown in Table IV.

Table IV

1200 Psig, 31.5 wt% Catalyst on Feed, 3500 SCF/B Hydrogen			
Slurry Hydrotreating Temperature, °F	760/720	750/690	730
Time on Temperature, Hours	1/1	1/1	4
Slurry Product Quality			
Wt% Sulfur	.029	.065	.047
Wt% Nitrogen	.054	.088	.086
Wt% Sats + 1R AR	69	63	63
Wt% 3+ R AR & Polars	16	18	22
Wt% Polar AR	0.6	1.2	1.6
MAT Conversion	63.5	59.9	64.1
MAT Coke	2.68	2.53	2.60

Comparing the results of the temperature staging experiments with the experiments of Comparative Example 1, which was run at a single temperature for 2 hours, it may be concluded that the temperature staging experiments provide both the high HDS, HDN and polar aromatics removal of the higher temperature experiments and the high heavy aromatics removal/saturates and 1 ring aromatics production of the lower temperature experiments. Referring to FIG. 2, it can be seen the temperature staging experiments provided lower MAT coke yields at any given MAT conversion. The lowest MAT coke yields were observed for the product from the 750/690 °F temperature staging experiment. The 760/720 °F temperature staging experiment showed lower heavy aromatics levels and higher saturates plus 1 ring aromatics levels than any two hour, single temperature experiment. In order to match the results of the two hour temperature staging experiment, a single temperature, say 730 °F, would require four hours.

### EXAMPLE 3

To further illustrate the present invention, a further experiment was conducted with the same catalyst and feed as in Comparative Example 1. The autoclave was heated to 720 °F under 1200 hydrogen pressure, and after two hours at reaction conditions, the autoclave was quenched. The catalyst was discharged from the autoclave, filtered and recharged to the autoclave with another 100 gms of the same feed. The same catalyst charge was filtered and recycled in the autoclave several times in order to line out catalyst performance. The results of this experiment along with a similar experiment at 760 °F are shown in Table V. In the similar experiment, catalyst from a temperature staging autoclave run, in which the autoclave was run at 760 °F for an hour and then 720 °F for an hour, was discharged, filtered and recycled to further autoclave temperature staging experiments. The temperature staging conditions and results for this experiment and a similar experiment at 800 and 720 °F are shown in Table V.

Table V

1200 Psig, 31.5 wt% Catalyst on Feed, 3500 SCF/B Hydrogen				
Slurry Hydrotreating Temperature, °F	760/720	800/720	720	760
Time on Temperature, Hours	1/1	1/1	2	2
Slurry Product Quality				
Wt% Sulfur	.062	.036	.126	.051
Wt% Nitrogen	.144	.092	.186	.092
Wt% Sats + 1R AR	65	64	61	61
Wt% 3+ R AR & Polars	20	20	23	24
Wt% Polar AR	1.8	1.4	2.7	1.5

Comparing the results of the temperature staging experiments with the experiments run at a single temperature for 2 hours, the temperature staging experiments with recycled catalyst provided both lower heavy aromatics levels and higher saturates plus 1 ring aromatics levels than any two hour, single temperature experiment. HDS, HDN and polar aromatics removal in the temperature staging experiments were as good or better than at single temperature experiments at the same average temperature.

The process of the invention has been described generally and by way of example with reference to particular embodiments for purposes of clarity and illustration only. It will be apparent to those skilled in the art from the foregoing that various modifications of the process and materials disclosed herein can be made without departure from the spirit and scope of the invention.

USSN 414,166 referred to herein corresponds with European patent application No. filed on or about 28 September 1990 and entitled "Slurry Hydrotreating Process", and which describes and claims a process for hydrotreating a heavy fossil fuel to hydrogenate heavy aromatics and remove sulfur, the process comprising:

reacting the heavy fossil fuel in a hydrotreating zone with hydrogen in the presence of a non-noble metal containing hydrotreating catalyst;  
separating the catalyst from the product of the hydrotreating zone;  
reactivating the catalyst in a reactivating zone, separate from the hydrotreating zone, by hydrogen stripping; and  
recycling the reactivated catalyst to the hydrotreating zone.

#### Notes

● HPLC denotes High Performance Liquid Chromatography.

● GC denotes Gas Chromatography.

● Mogas is an abbreviation for motor gasoline.

● SCF (standardized cubic foot) = 28.316 liter.

● B (barrel) = 158.9 liter.

● Mesh sizes are Tyler series.

#### Claims

1. A process for the hydrotreating of a hydrocarbonaceous material to improve the quality of the hydrotreated product for use as a feed to a catalytic cracking unit, comprising:

(1) contacting the hydrocarbonaceous material feed with hydrogen in a relatively high temperature first hydrotreating zone in the presence of a hydrotreating catalyst slurry such that substantial hydrodenitrogenation and aromatics saturation of the feed is carried out, and wherein multi-ring aromatics are saturated in preference to either single-ring aromatics or saturates;

(2) contacting the effluent from the first hydrotreating zone in the presence of a hydrotreating catalyst slurry with further hydrogen in a relatively low temperature second hydrotreating zone; and

(3) separating catalyst and a gaseous mixture comprising hydrogen from the product of the second hydrotreating zone to yield a hydrotreated product.

2. The process of claim 1, wherein the feed is a heavy catalytic cracking cycle oil, coker oil, or vacuum gas oil, which may have been obtained from petroleum, coal, shale oil, bitumen, tar sand or synfuel (e.g., by a conversion process).

3. The process of claim 1 or claim 2 comprising additional staged hydrotreating zones wherein additional hydrotreatment is effected.

4. The process of any one of claims 1 to 3 wherein the feed boils predominantly in the range of from 500 to 1200 °F (260 to 648.9 °C).

5. The process of any one of claims 1 to 4 wherein the first hydrotreating zone is operated at a temperature of from 700 to 800 °F (371.1 to 426.7 °C), e.g., from 750 to 800 °F (398.9 to 426.7 °C).

6. The process of any one of claims 1 to 5 wherein the second hydrotreating zone is operated at a temperature of from 650 to 750 °F (343.3 to 398.9 °C), e.g., from 675 to 725 °F (357.2 to 385.0 °C).

7. The process of any one of claims 1 to 6 wherein the catalyst is comprised of molybdenum sulfide, and the catalyst may further comprise nickel and/or cobalt.

8. The process of any one of claims 1 to 7 wherein the catalyst is supported on an inorganic oxide material, e.g., alumina, silica, titania, silica, titania, silica alumina, silica magnesia, and mixtures thereof.



9. The process of any one of claims 1 to 8 wherein the catalyst particles' size is from 10  $\mu\text{m}$  to 1/8 inch (3.175 mm) in average diameter, e.g., from 10  $\mu\text{m}$  to 400  $\mu\text{m}$  in average diameter.
10. The process of any one of claims 1 to 9 wherein the surface area of the catalyst is from 80 to 400  $\text{m}^2/\text{g}$ .
11. A process for the hydrotreating and catalytic cracking of a gas oil feed having a boiling point of 500 to 1200 °F (260 to 648.9 °C) and a 2+ ring aromatics content of 50% or more, which process comprises:
- (1) contacting said gas oil feed with hydrogen in a first hydrotreating zone at a temperature of between 750 and 800 °F (398.9 to 426.7 °C) in the presence of a hydrotreating catalyst slurry such that substantial hydrodenitrogenation and aromatics saturation of the feed is carried out, and wherein the weight percent of multi-ring aromatics is decreased while the weight percent of saturates and single-ring aromatics is increased;
  - (2) contacting the effluent from the first hydrotreating zone in the presence of a hydrotreating catalyst slurry with further hydrogen in a second hydrotreating zone at a temperature between 650 and 750 °F (343.3 to 398.9 °C);
  - (3) separating catalyst and a gaseous mixture comprising hydrogen from the product of the second hydrotreating zone to yield a hydrotreated product; and
  - (4) catalytic cracking said hydrotreated product.
12. The process of any one of claims 1 to 11 wherein said feed has a boiling range of from 500 to 1200 °F (260 to 648.9 °C) or boils within said range and has a 2+ ring aromatics content of 50% or more.
13. The process of any one of claims 1 to 12 wherein the content of 3+ ring aromatics is 25% or more.
14. The process of any one of claims 1 to 13 comprising recovering a hydrotreated product having a lower heavy aromatics level and a higher saturates plus 1-ring aromatics level than the feed.

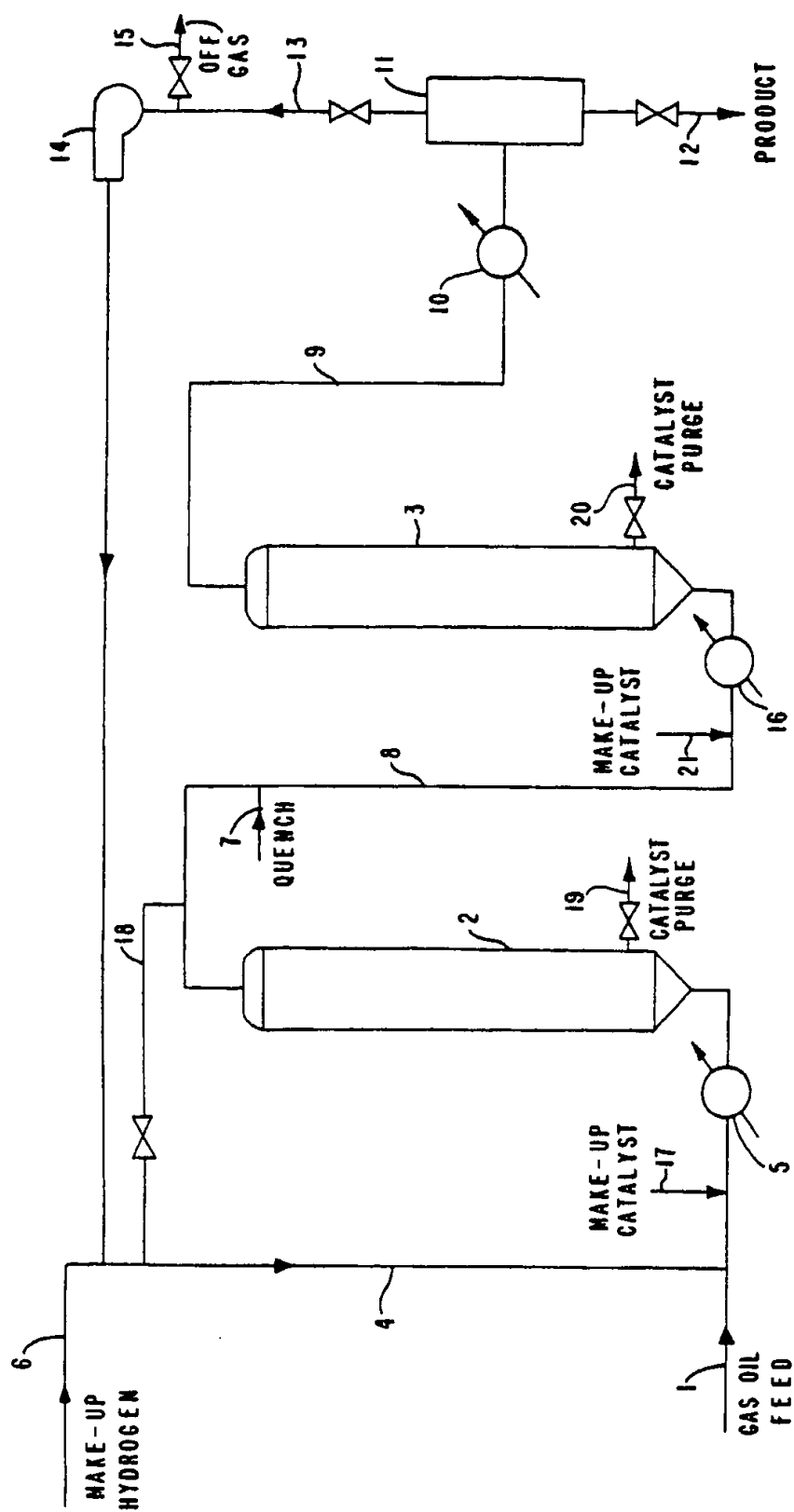


FIG. 1

FIG. 2

